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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

TECHNICAL MEMORANDUM X-701

STATIC AERODYNAMIC CHARACTERISTICS OF A 1/9-SCALE MODEL OF THE ESCAPE AND EXIT CONFIGURATIONS OF THE PROJECT MERCURY SPACECRAFT AT MACH NUMBERS FROM 2.30 TO 4.65*

By Roger H. Fournier

SUMMARY

An investigation has been conducted in the Langley Unitary Plan wind tunnel to determine the static aerodynamic characteristics of a 1/9-scale model of the exit and the escape configurations of the Project Mercury spacecraft at Mach numbers from 2.30 to 4.65. The exit configuration was equipped with a flap-type destabilizer. The purpose of the destabilizing device is to assure that the spacecraft assumes the proper reentry attitude upon reentering the earth's atmosphere in the event that the primary reaction-control system fails. The flap-type destabilizing device produced the desired effect up to a Mach number of 3.94 above which it did not prove to be as effective. The escape configuration was investigated with a Marman clamp and a modified parachute housing (large-diameter canister) and also with the small-diameter parachute housing. The results show that the escape configuration trims with positive stability near angles of attack of 0° through the Mach number range of the tests. For Mach numbers of 3.94 and 4.65, unstable characteristics are exhibited at the higher angles of attack.

INTRODUCTION

In order to obtain information for use in the design of a blunt, nonlifting body which could be used as a reentry vehicle, various wind-tunnel investigations have been conducted by the National Aeronautics and Space Administration (see refs. 1 to 7). Results of these investigations have aided in the design and development of a spacecraft to carry man into space and return safely to earth. The development of

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the manned system for the initial orbital flights has been designated Project Mercury. In support of Project Mercury, the Langley Research Center has conducted extensive wind-tunnel investigations. The investigations were broadened by consideration of the many possible aerodynamic configurations which might exist during planned staging for exit, reentry, and emergency situations. As part of these investigations, the Langley Unitary Plan wind tunnel has been utilized in an investigation of the static aerodynamic characteristics of a 1/9-scale model of the exit and the escape configurations. Tests were conducted at Mach numbers from 2.30 to 4.65. The test angle-of-attack range for the escape configuration generally extended from -5° to 24°, except that one escape configuration was tested from -23° to 24°. The exit configuration was tested through an angle-of-attack range from -10° to 83°. The Reynolds numbers varied from 2.20×10^6 to 5.22×10^6. The results of the investigation presented herein are compared with the results presented in reference 7 for an earlier spacecraft.

SYMBOLS

The aerodynamic force and moment data are referred to the body system of axes (fig. 1). The reference moment-center locations are shown in figure 2. These moment-center locations correspond to the center-of-gravity location of the full-scale spacecraft.

C_A axial-force coefficient, $\frac{\text{Axial force}}{qS}$

$C_{A,\alpha=0}$ axial-force coefficient at $\alpha = 0^\circ$

$C_{A,c}$ chamber axial-force coefficient, $\frac{\text{Chamber axial force}}{qS}$

C_m pitching-moment coefficient, $\frac{\text{Pitching moment}}{qSd}$

C_{m_α} slope of pitching-moment-coefficient curve at $\alpha = 0^\circ$, $\frac{\partial C_m}{\partial \alpha}$, per deg

C_N normal-force coefficient, $\frac{\text{Normal force}}{qS}$

C_{N_α} slope of normal-force-coefficient curve at $\alpha = 0^\circ$, $\frac{\partial C_N}{\partial \alpha}$, per deg

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d	maximum diameter of model, 8.278 in.
M	free-stream Mach number
q	free-stream dynamic pressure, lb/sq ft
R	Reynolds number based on maximum model diameter and free-stream conditions
S	maximum cross-sectional area, 0.374 sq ft
T_t	stagnation temperature, $^{\circ}F$
α	angle of attack of center line of model, deg

APPARATUS AND METHODS

Tunnel

Tests were conducted in the high Mach number test section of the Langley Unitary Plan wind tunnel. The test section is a variable-pressure continuous-flow tunnel and is 4 feet square and approximately 7 feet long. The nozzle leading to the test section is of the asymmetric sliding-block type which permits a continuous variation in test-section Mach number from approximately 2.30 to 4.65.

Models

Drawings and dimensions of the 1/9-scale model used in this investigation are presented in figure 2, and photographs of the model are presented in figure 3. The model was tested both with and without the escape system and also with the large- and small-diameter parachute housings. The configurations will be referred to as the escape configuration (spacecraft with escape system) and the exit configuration (spacecraft without escape system). The model was similar to that of reference 7 with the following exceptions:

(1) A wedge-shaped ring, referred to as a Marman clamp, was added to the base of the escape tower. This ring houses the escape-tower separation mechanism.

(2) A different flap-type destabilizer was added to the antenna housing of the exit configuration in place of the previously tested flap.

(3) The parachute canister was enlarged for both the exit and escape configurations.

Test Conditions

Tests were performed at the following conditions:

M	Configuration	Angle-of-attack range, deg	q, lb/sq ft	R	T_t, ^{o}F
2.30	Exit	-10 to 83	798.5	2.45×10^6	150
2.87	Exit	-10 to 83	679.7	2.39	150
3.94	Exit	-10 to 83	474.9	2.20	175
2.50	Escape	-23 to 24	786.4	2.50	150
2.87	Escape	-23 to 24	713.3	2.50	150
3.94	Escape	-23 to 24	539.8	2.50	175
4.65	Escape	-23 to 24	411.7	2.50	175
2.50	Escape	-5 to 24	1,386.3	4.40	150
2.87	Escape	-5 to 24	1,481.5	5.22	150

Three separate sting arrangements were required to obtain an angle-of-attack range from -23^{o} to 84^{o}. These arrangements can be seen in the schlieren photographs (fig. 4).

CORRECTION AND ACCURACY

Tunnel pressure gradients in the region of the model have been found to be sufficiently small so as not to induce any measurable buoyancy effects on the model. However, angularity surveys indicate that a flow misalinement exists, therefore, the angles of attack have been corrected for this misalinement; and in addition, all angles of attack have been corrected for deflections of the balance combination due to aerodynamic loads. The axial-force coefficients presented are not adjusted for measured chamber-pressure levels. Chamber axial force, however, has been determined and is presented in coefficient form in figures 5 and 6.

Accuracies of the present data based upon balance calibrations and repeatability of the results are estimated to be within the following limits:

C_A	±0.020
$C_{A,c}$	±0.001
C_m	±0.010
C_N	±0.050
M (for M = 2.30, 2.50, 2.87, and 3.94)	±0.015
M (for M = 4.65)	±0.050
α, deg	±0.10

PRESENTATION OF RESULTS

The results of the investigation are presented in the following figures:

	Figure
Typical schlieren photographs	4
Chamber axial-force coefficients of the escape configuration with large-diameter canister and Marman clamp	5
Chamber axial-force coefficients of the exit configuration	6
Effect of change in Reynolds number on the aerodynamic characteristics in pitch of the escape configuration	7
Effect of change in size of the parachute housing (canister) and the addition of a Marman clamp on the aerodynamic characteristics in pitch of the escape configuration	8
Aerodynamic characteristics in pitch of the exit configuration	9
Summary of the aerodynamic characteristics in pitch of the exit and escape configurations	10

DISCUSSION OF RESULTS

Escape Configuration

Results presented in figure 7 indicate that change in the Reynolds number from 2.50×10^6 to 5.22×10^6 had negligible effects on the aerodynamic characteristics of the escape configuration.

Results presented in figure 8 and summarized in figure 10 indicate that all the escape configurations were statically stable at $\alpha = 0^\circ$ and also exhibited positive normal-force-coefficient-curve slopes over the test angle-of-attack and Mach number ranges. The enlarged parachute

canister and the addition of the Marman clamp had a slight destabilizing effect on the longitudinal stability C_{m_α}, but this effect reverses at Mach numbers above 4.30 and results in a more stable condition.

Exit Configuration

Results for the exit configuration are presented in figure 9 and are summarized in figure 10. These results are comparable to those presented for the exit configuration of reference 7, differing only in the addition of a different destabilizing flap to the present model. The results of this investigation indicate that for all test Mach numbers, the flap-type destabilizer had the desired effect of producing a pitching moment at zero angle of attack and of preventing the model from trimming at that point. At $M = 3.94$ the exit configuration showed a constant value for C_m near an angle of attack of zero. The destabilizer is a safety device which will aid in the proper alinement of the spacecraft (heat shield forward) upon reentering the earth's atmosphere.

The overall longitudinal aerodynamic characteristics of the exit configurations were little changed from those of the model of reference 7. The C_{m_α} is positive at the lower Mach numbers but becomes zero at a Mach number of 3.94 in both instances. The slope of the normal-force-coefficient curve is positive for angles of attack up to about 60° where it becomes zero.

CONCLUDING REMARKS

A wind-tunnel investigation has been conducted in the Langley Unitary Plan wind tunnel to determine the static aerodynamic characteristics of a 1/9-scale model of the exit and the escape configurations of the Project Mercury spacecraft at Mach numbers from 2.30 to 4.65. The following conclusions were made:

1. The escape configuration trims with positive stability near an angle of attack of 0° for all Mach numbers. Unstable characteristics are shown at the high angles of attack.

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2. The pitching moment caused by the flap-type destabilizer on the exit configuration assures an untrimmed and an essentially unstable condition of the spacecraft at all positive angles of attack and Mach numbers of this investigation.

Langley Research Center,
National Aeronautics and Space Administration,
Langley Station, Hampton, Va., May 18, 1962.

REFERENCES

1. Turner, Kenneth L., and Shaw, David S.: Wind-Tunnel Investigation at Mach Numbers From 1.60 to 4.50 of the Static-Stability Characteristics of Two Nonlifting Vehicles Suitable for Reentry. NASA MEMO 3-2-59L, 1959.

2. Shaw, David S., and Turner, Kenneth L.: Wind-Tunnel Investigation of Static Aerodynamic Characteristics of a 1/9-Scale Model of a Possible Reentry Capsule at Mach Numbers From 2.29 to 4.65. NASA TM X-233, 1959.

3. Carter, Howard S., Kolenkiewicz, Ronald, and English, Roland D.: Principal Results From Wind-Tunnel Stability Tests of Several Proposed Space Capsule Models Up to an Angle of Attack of 33°. NASA TM X-21, 1959.

4. Pearson, Albin O.: Wind-Tunnel Investigation at Mach Numbers From 0.40 to 1.14 of the Static Aerodynamic Characterisitcs of a Nonlifting Vehicle Suitable for Reentry. NASA MEMO 4-13-59L, 1959.

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6. Pearson, Albin O.: Wind-Tunnel Investigation at Mach Numbers From 0.50 to 1.14 of the Static Aerodynamic Characteristics of a Model of a Project Mercury Capsule. NASA TM X-292, 1960.

7. Shaw, David S., and Turner, Kenneth L.: Wind-Tunnel Investigation of Static Aerodynamic Characteristics of a 1/9-Scale Model of a Project Mercury Capsule at Mach Numbers From 1.60 to 4.65. NASA TM X-291, 1960.

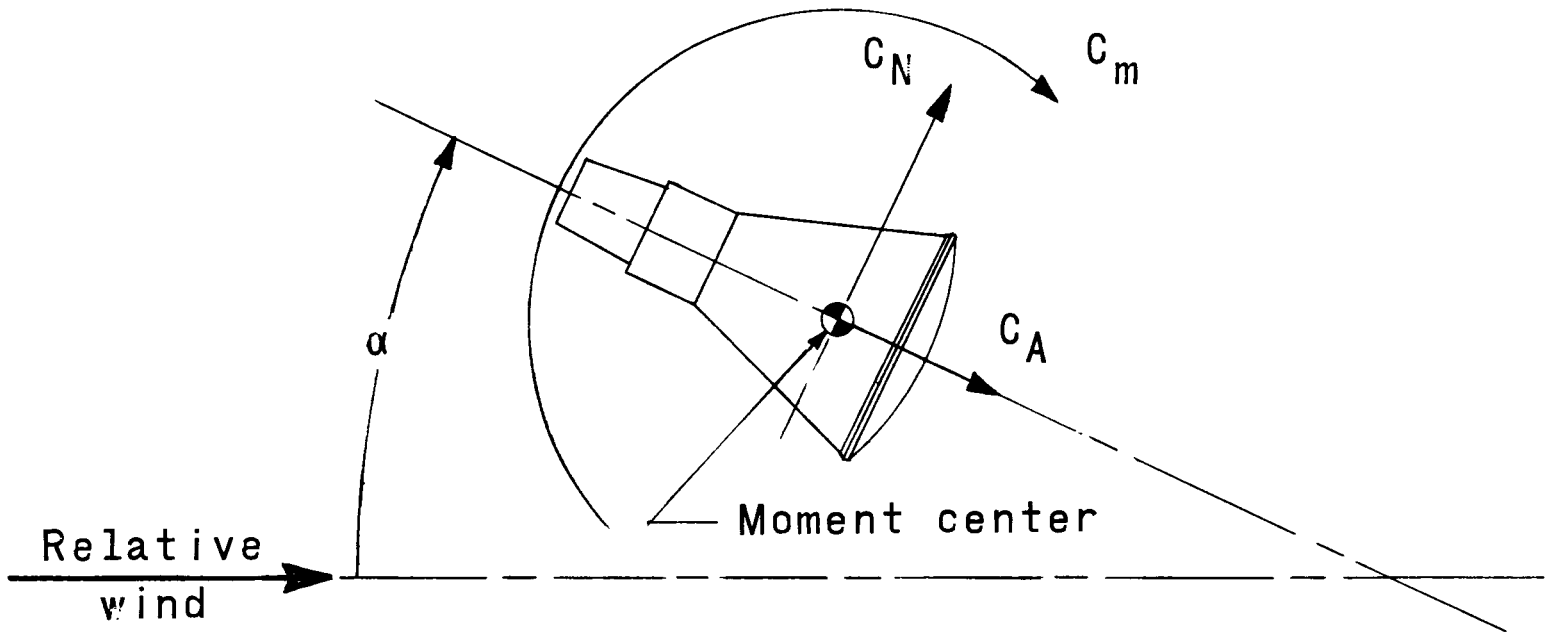
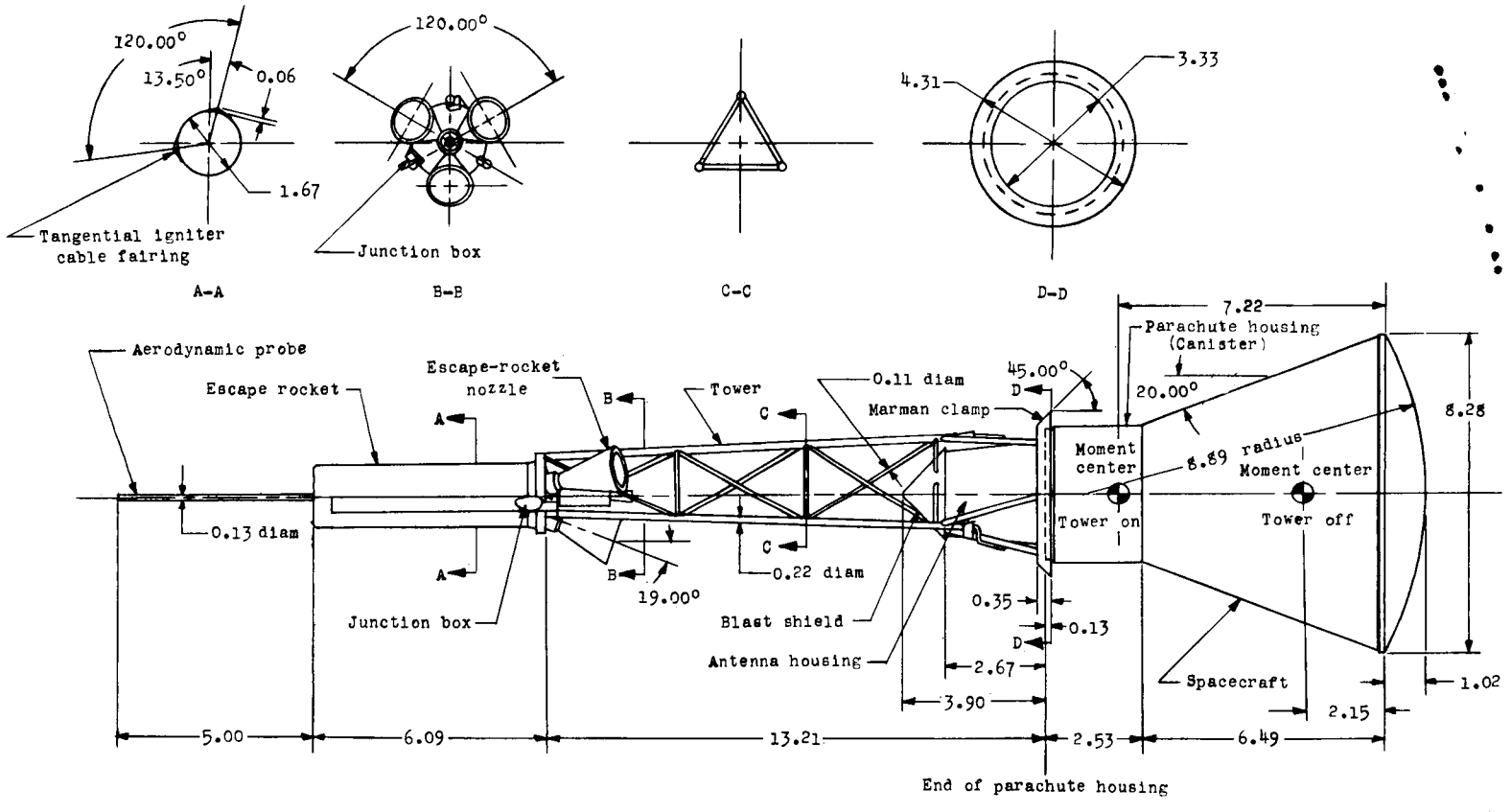
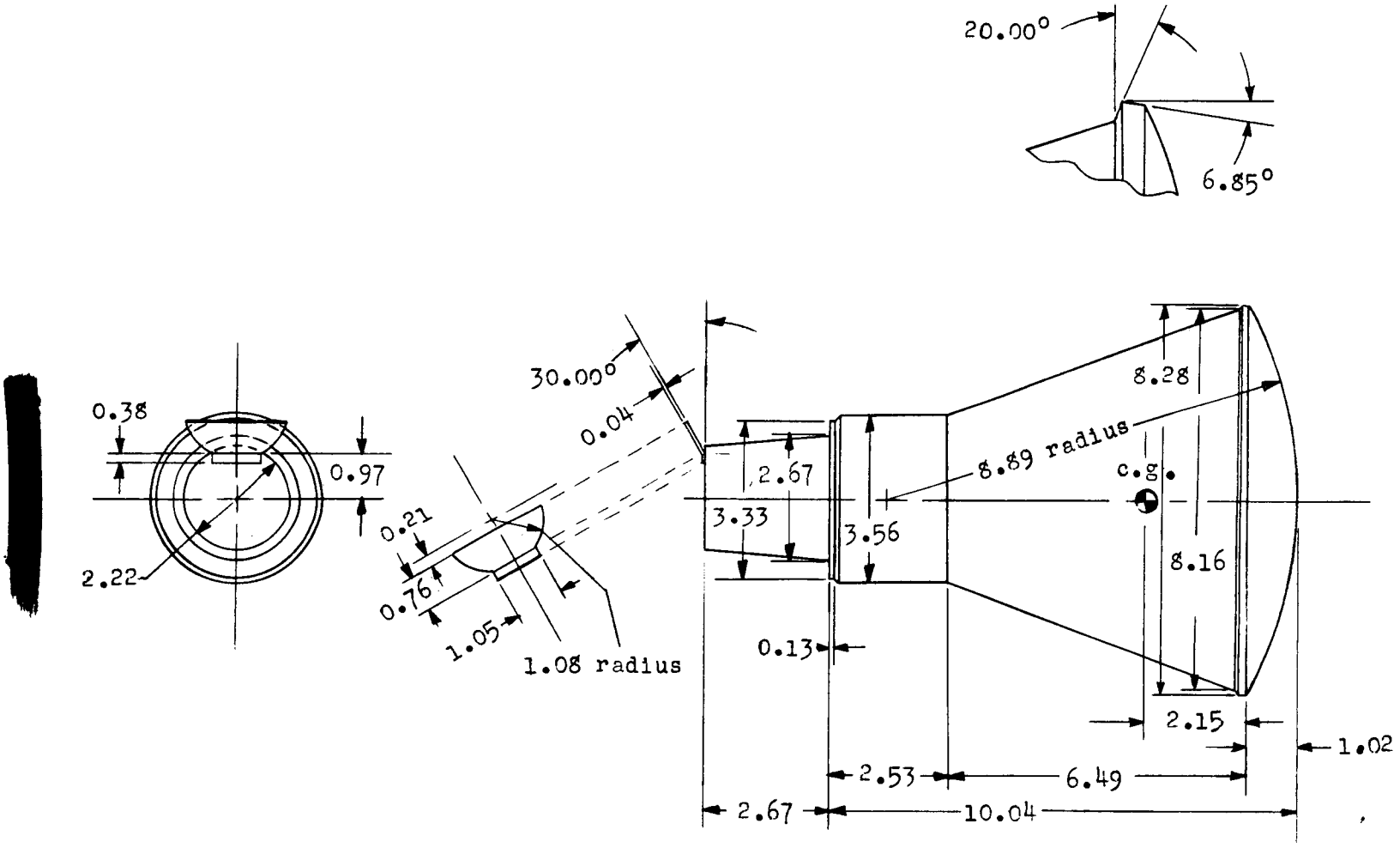


Figure 1.- Body-axis system (exit configuration shown). Arrows indicate positive direction.



(a) Escape configuration.

Figure 2.- Drawings and dimensions of models. All dimensions are in inches unless otherwise noted.



(b) Exit configuration.

Figure 2.- Concluded.

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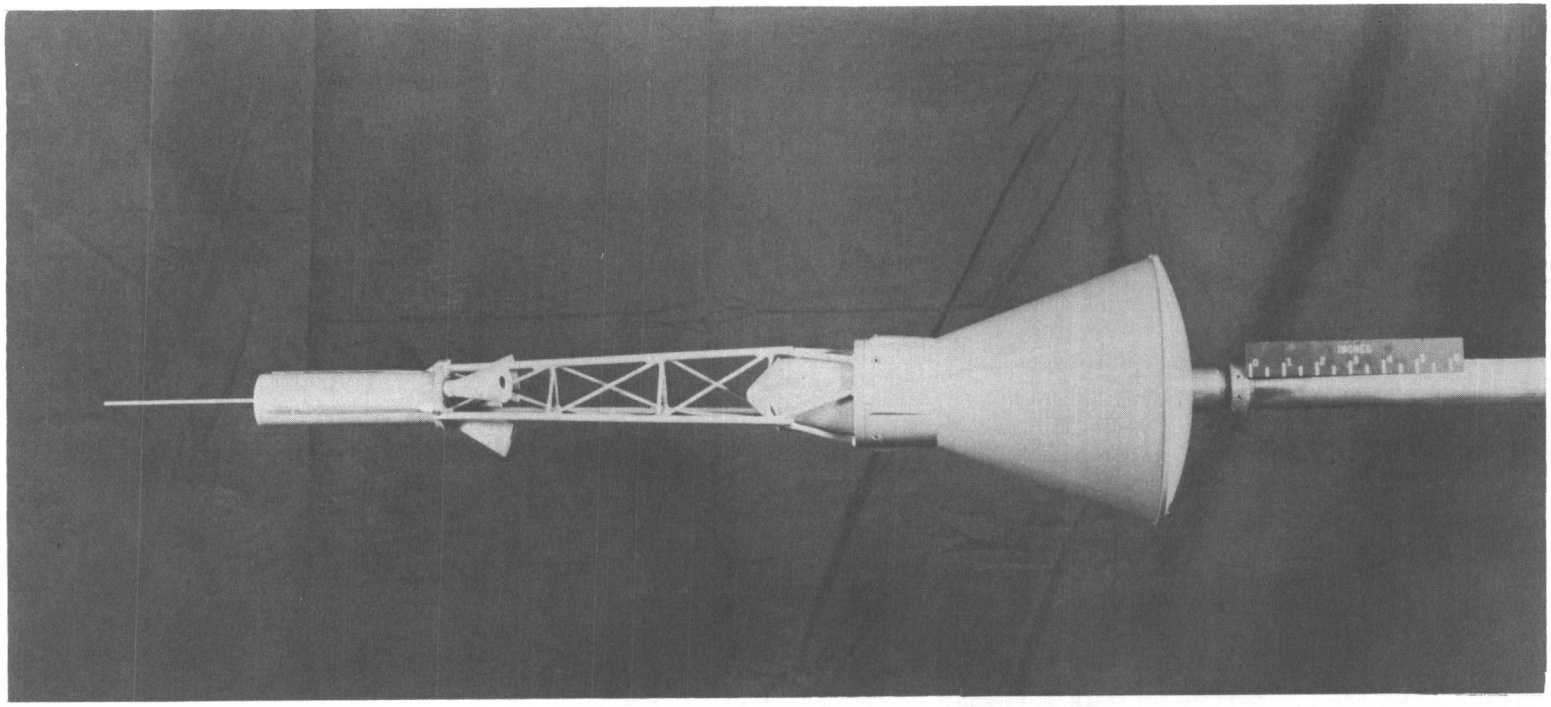

(a) Escape configuration with small-diameter canister. L-59-6617

Figure 3.- Photographs of model.

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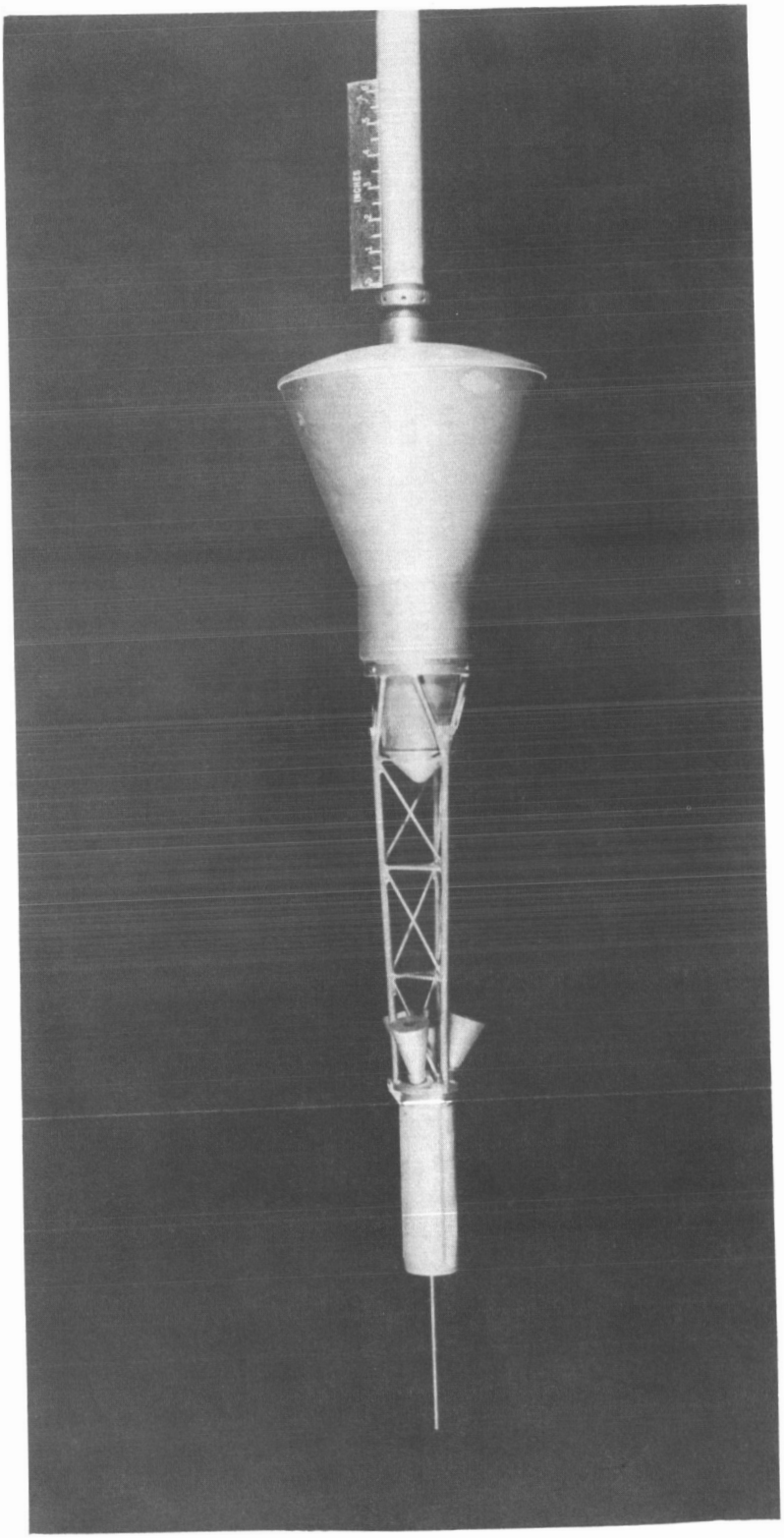

L-60-2983

(b) Escape configuration with large-diameter canister.

Figure 3.- Continued.

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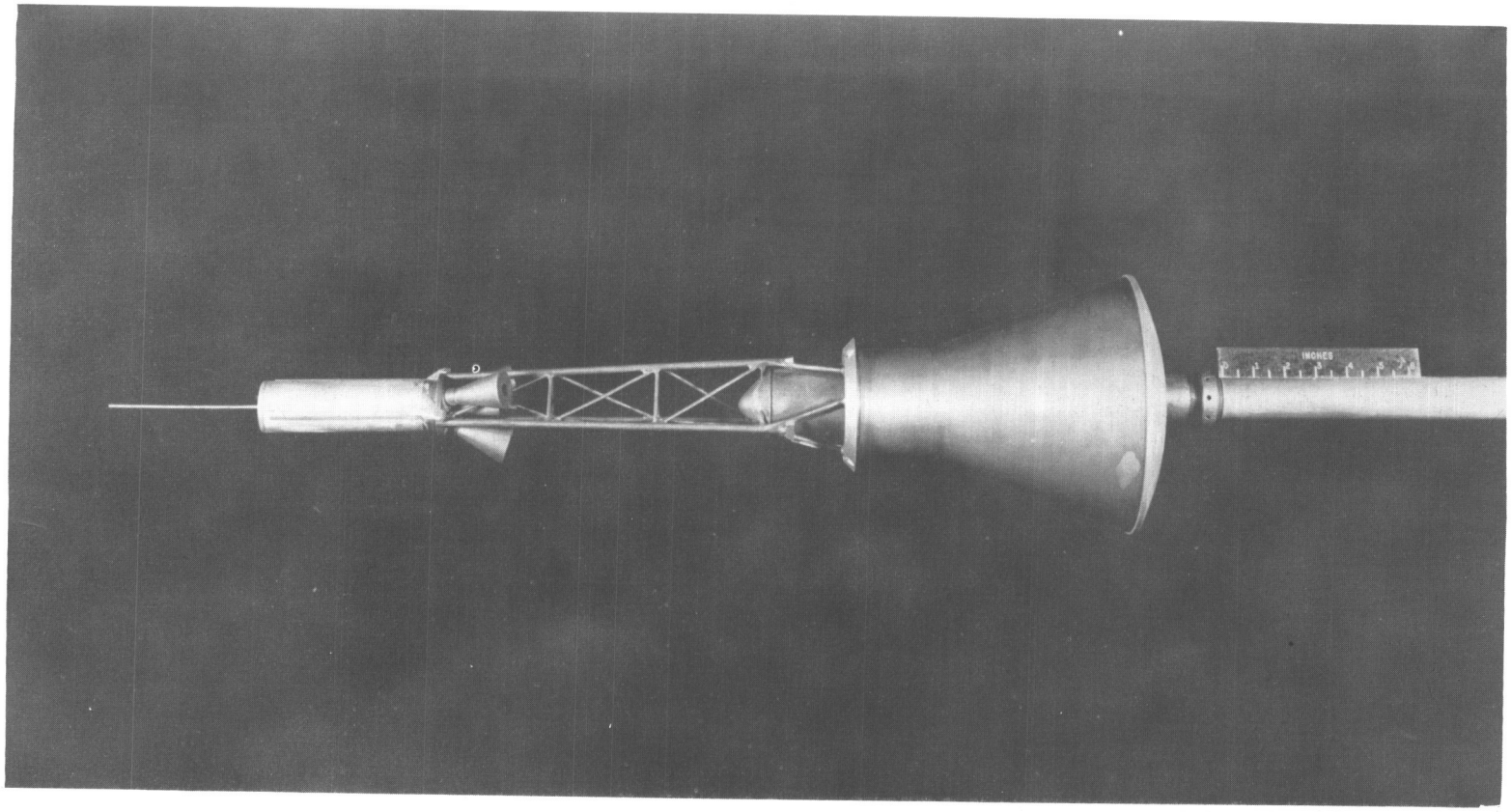

(c) Escape configuration with large-diameter canister and Marman clamp. L-60-2975

Figure 3.- Continued.

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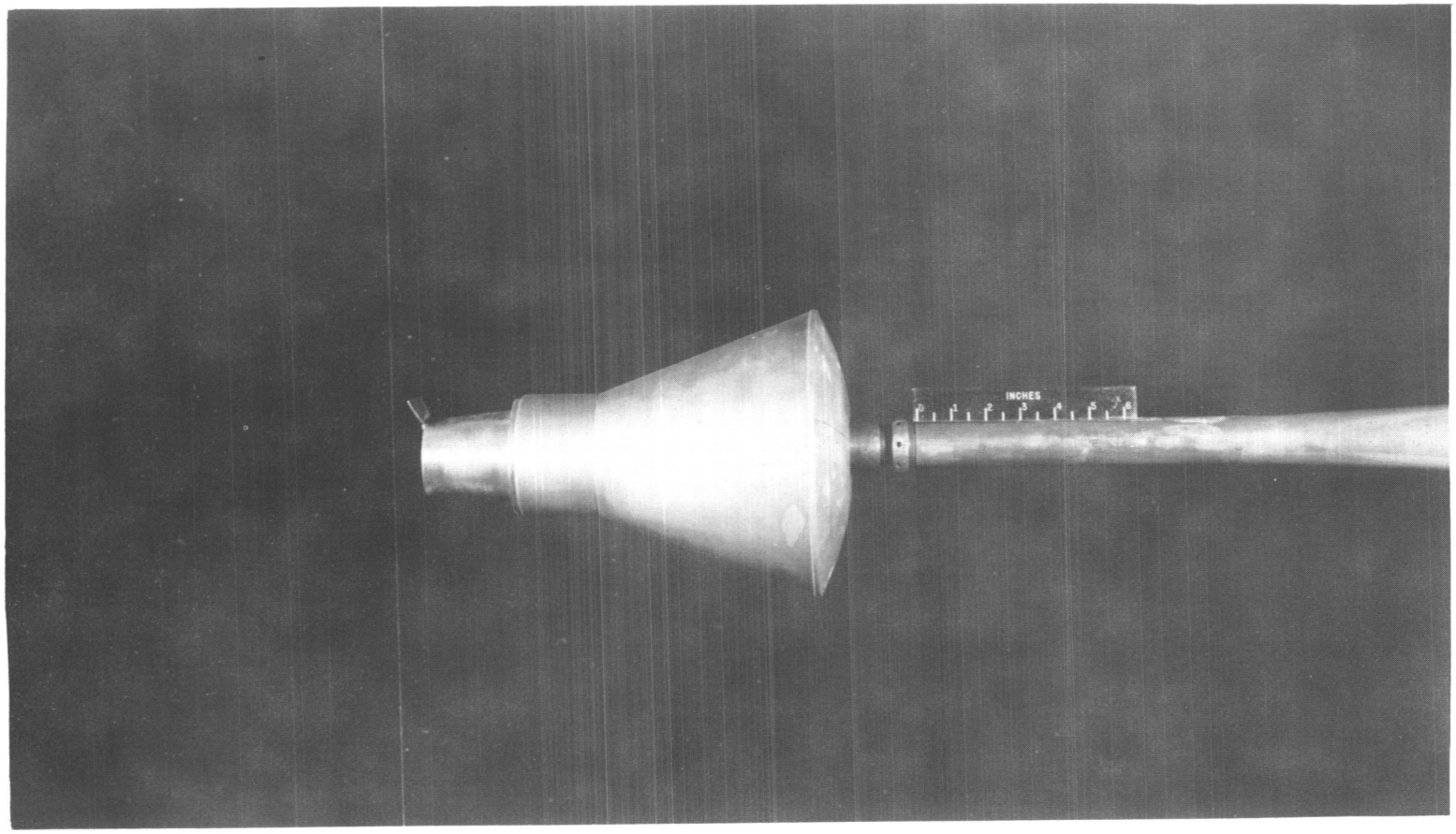

(d) Exit configuration with large-diameter canister. L-60-2977

Figure 3.- Concluded.

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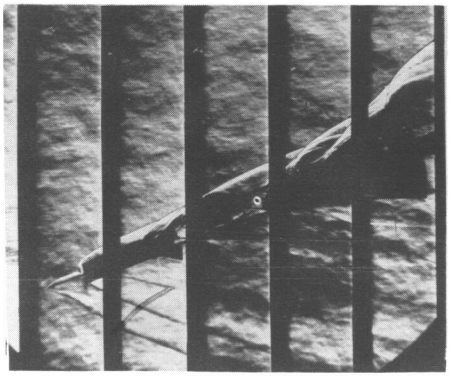
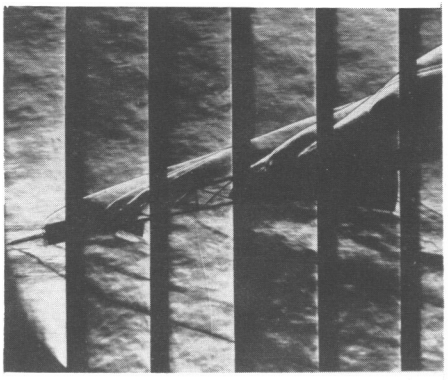
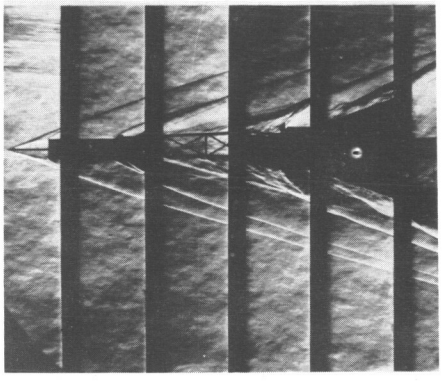


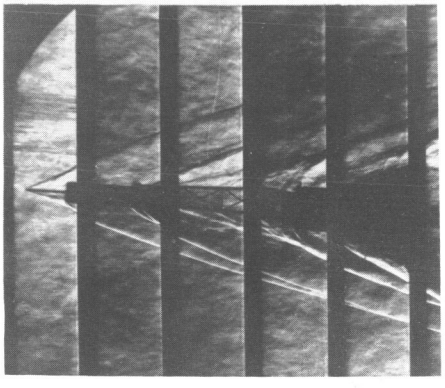
α = -19.2°



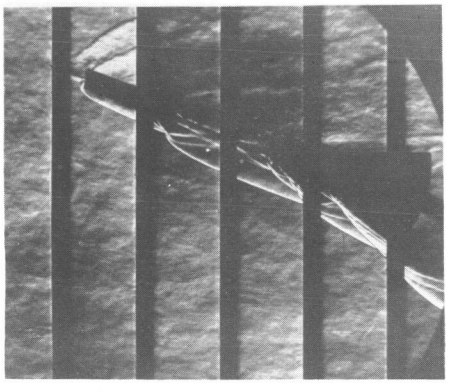
α = -11.0°



α = 0.3°



α = 2.8°



α = 19.2°

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(a) Escape configuration with large-diameter canister and Marman clamp.

Figure 4.- Typical schlieren photographs. M = 3.94; R = 2.50×10^6.

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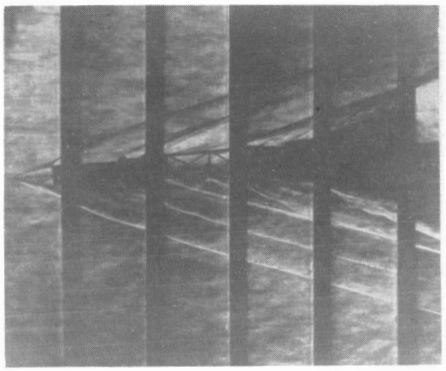
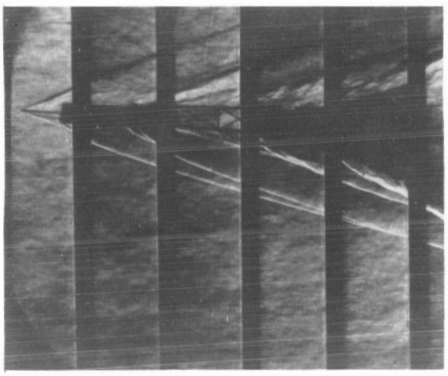
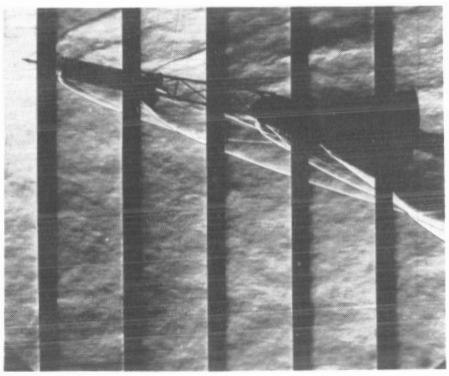


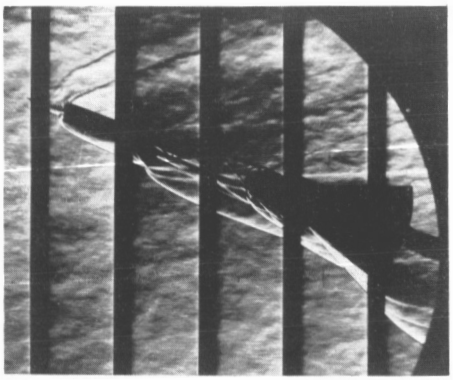
α = -3.4°



α = 2.8°



α = 11.0°



α = 19.2°

(b) Escape configuration without Marman clamp. L-62-2060

Figure 4.- Continued.

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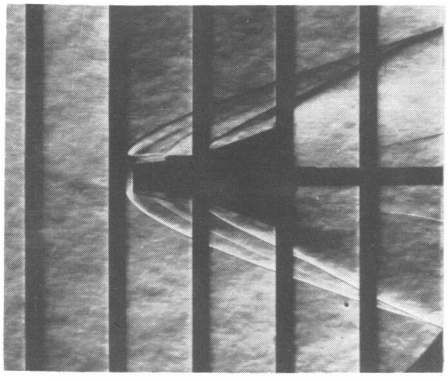
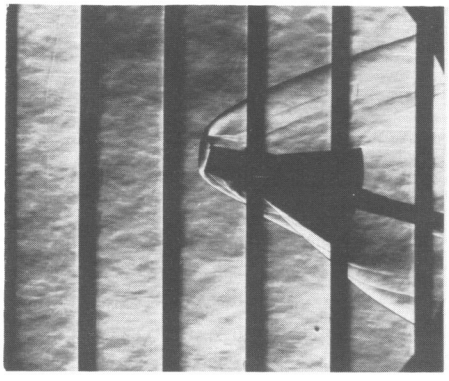
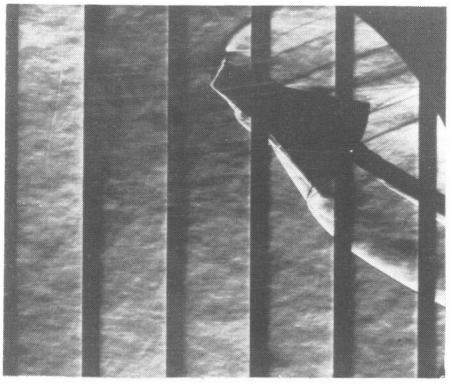


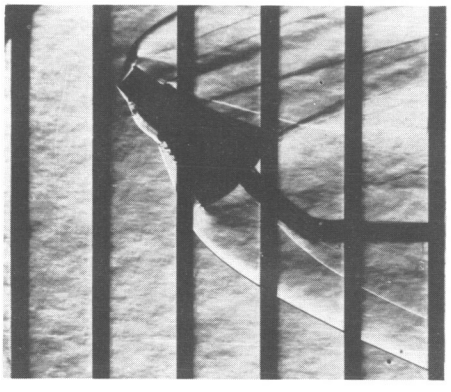
α ≈ 0.8°



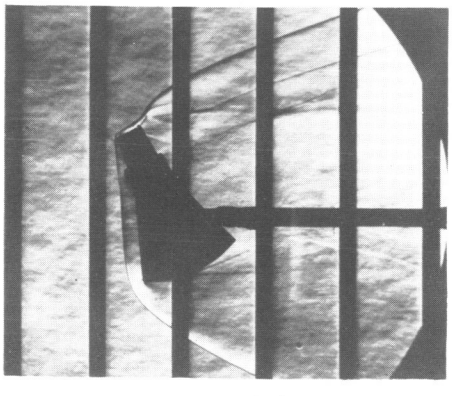
α ≈ 16.5°



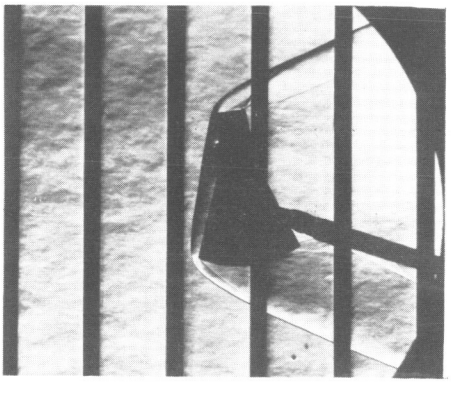
α ≈ 29.2°



α = 44.2°



α = 64.4°



α = 81.9°

(c) Exit configuration. L-62-2061

Figure 4.- Concluded.

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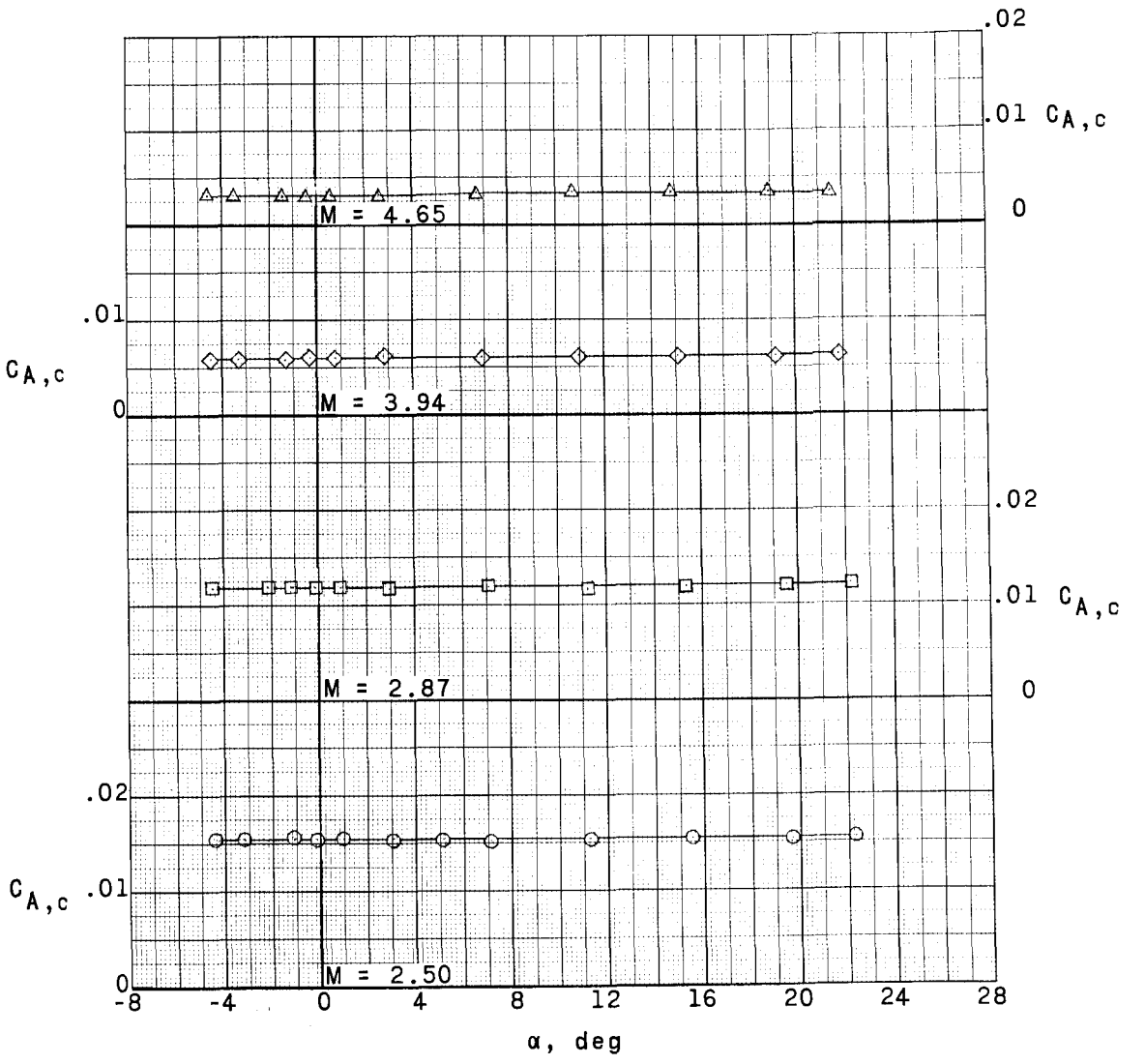

Figure 5.- Chamber axial-force coefficients of the escape configuration with large-diameter canister and Marman clamp.

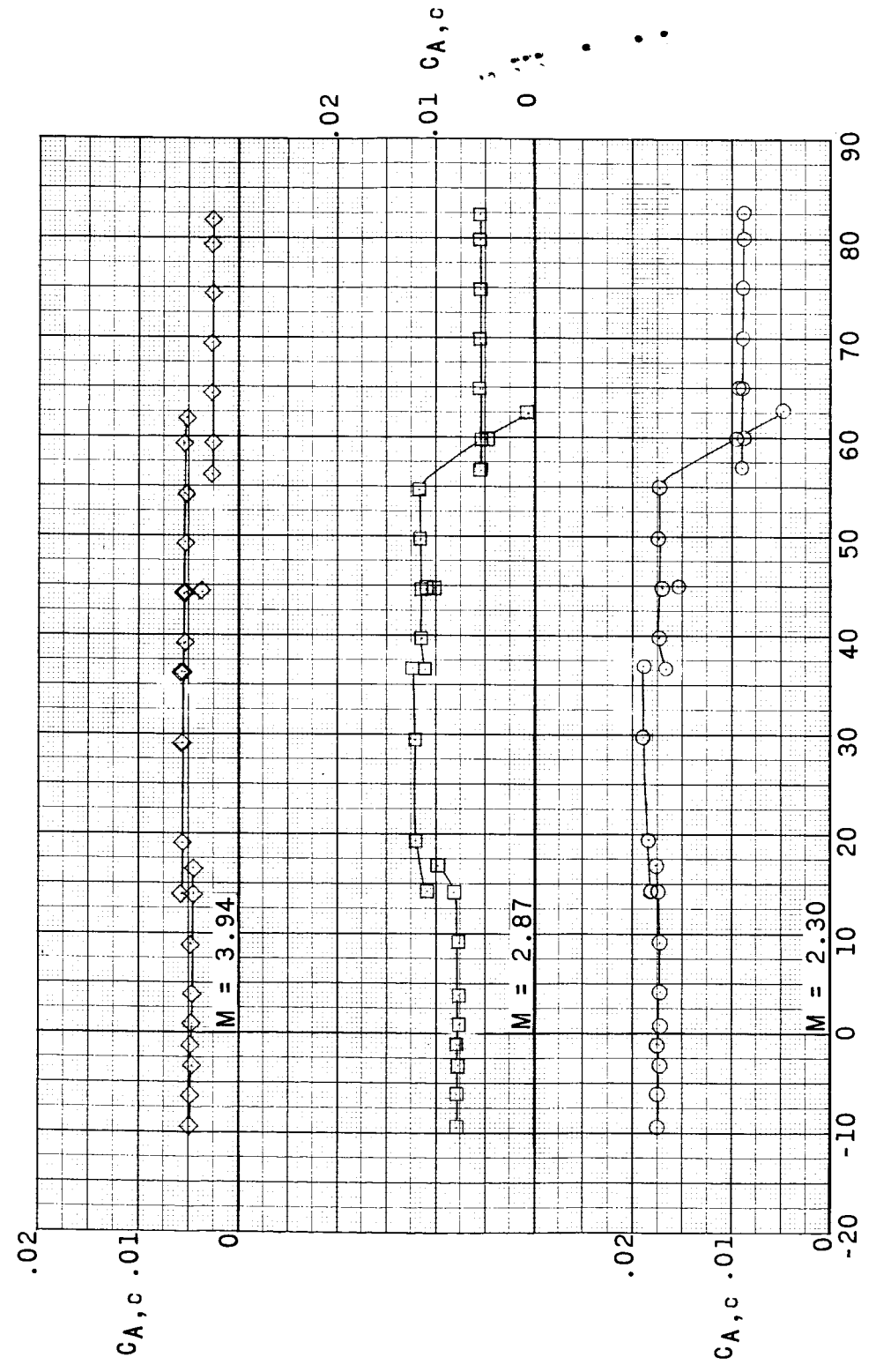

Figure 6.- Chamber axial-force coefficients of the exit configuration.

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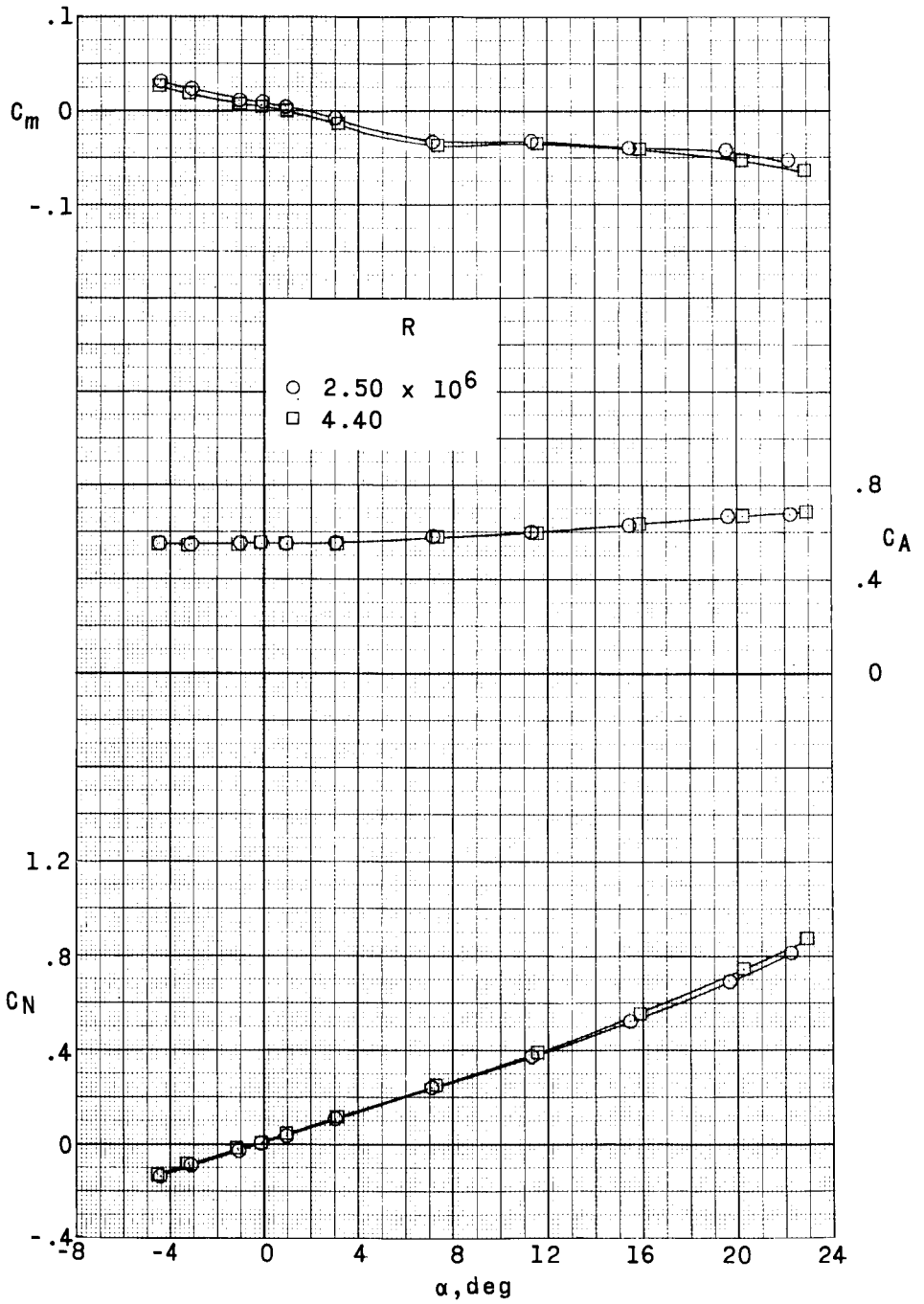

(a) M = 2.50.

Figure 7.- Effect of change in Reynolds number on the aerodynamic characteristics in pitch of the escape configuration.

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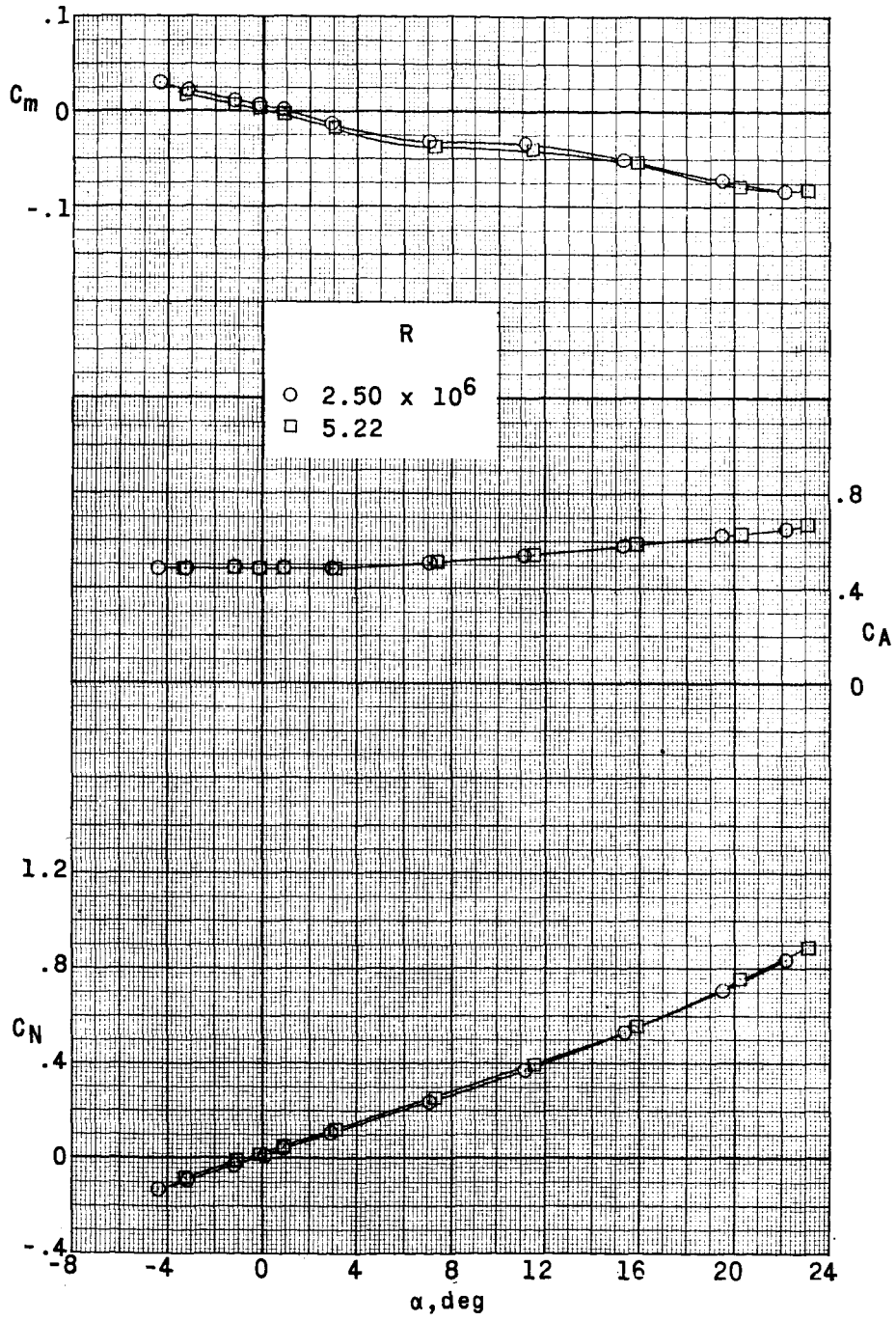
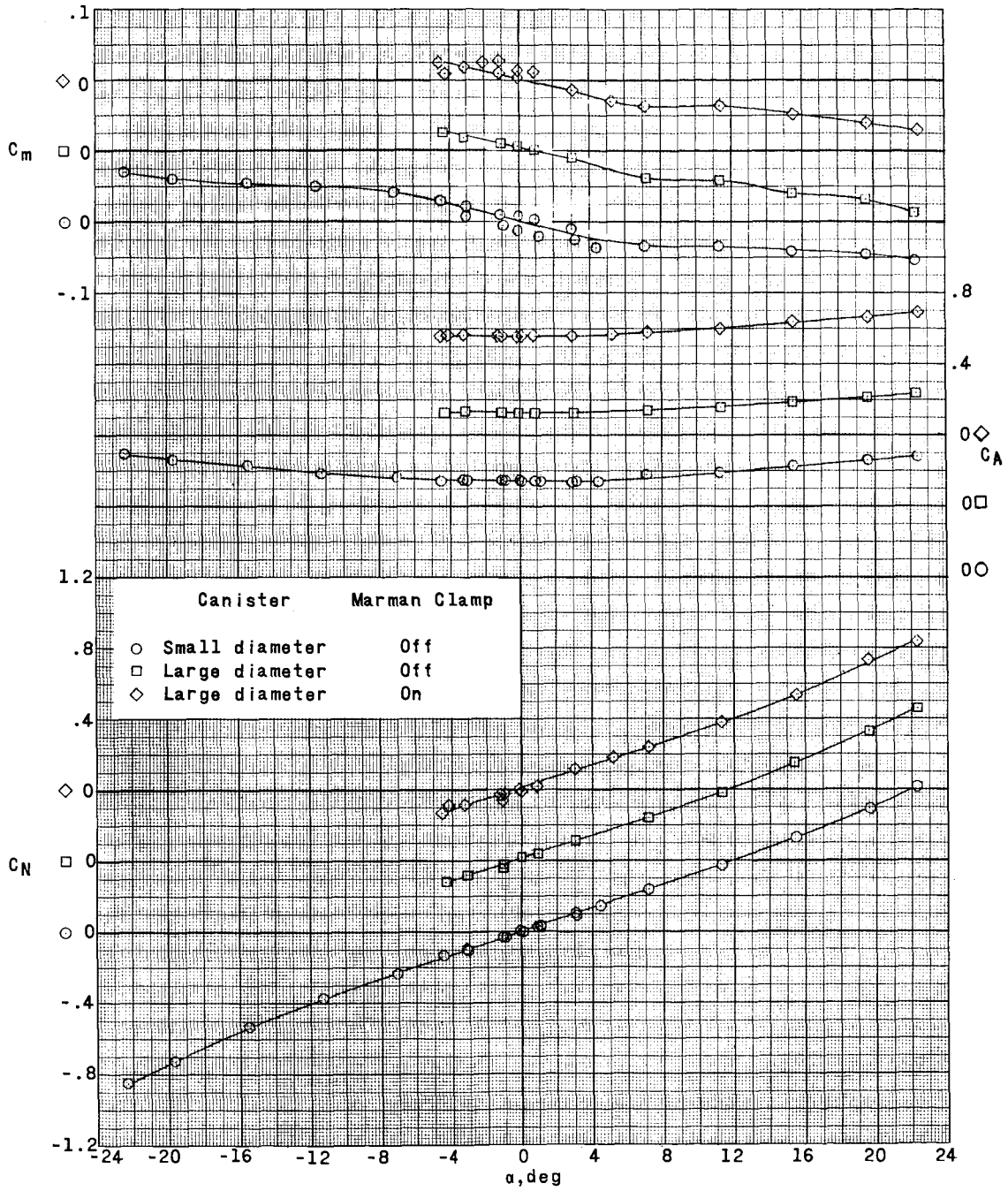


(b) M = 2.87.

Figure 7.- Concluded.

[redacted]



(a) M = 2.50.

Figure 8.- Effect of the change in size of the parachute housing (canister) and the addition of a Marman clamp on the aerodynamic characteristics in pitch of the escape configuration.

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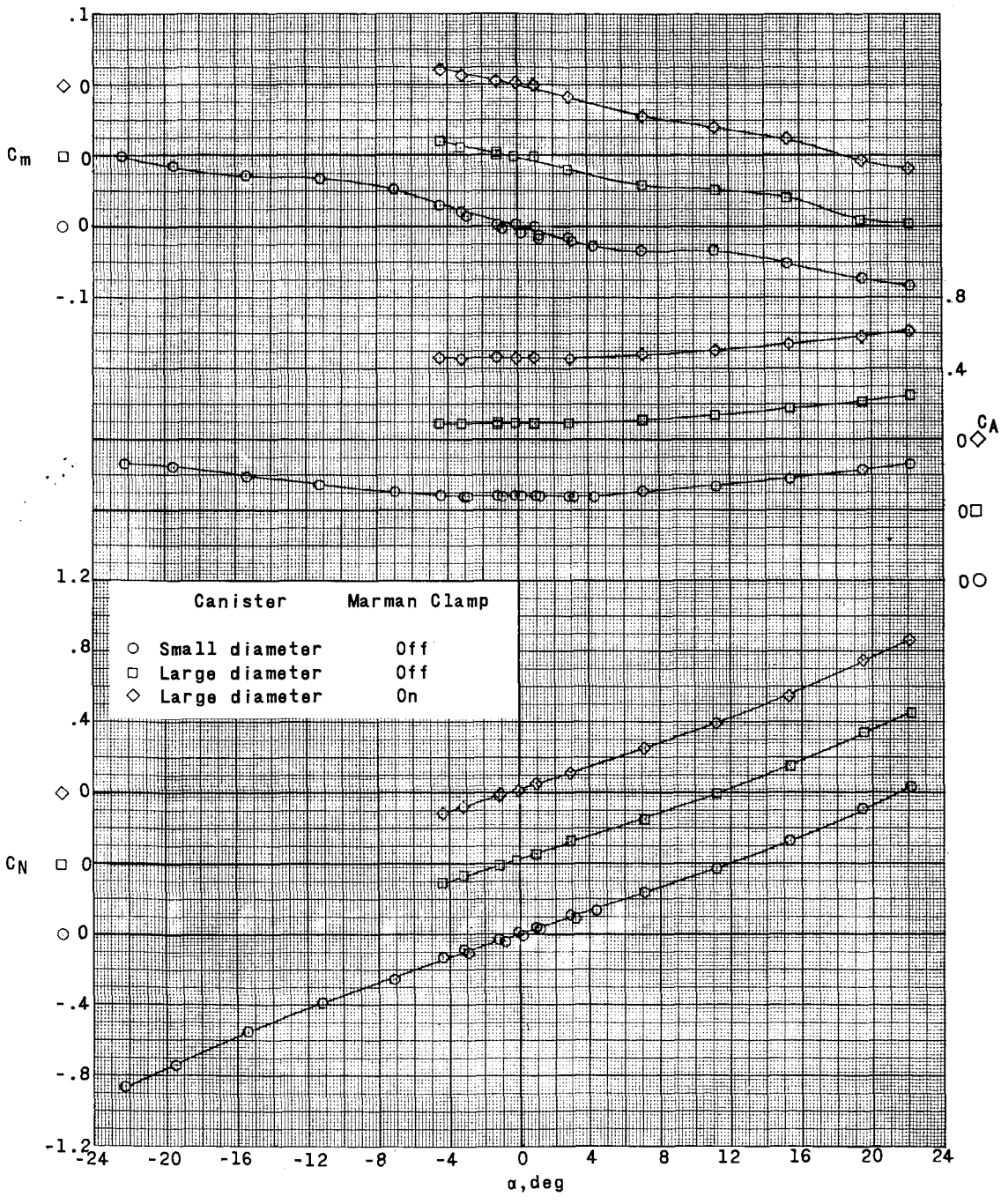
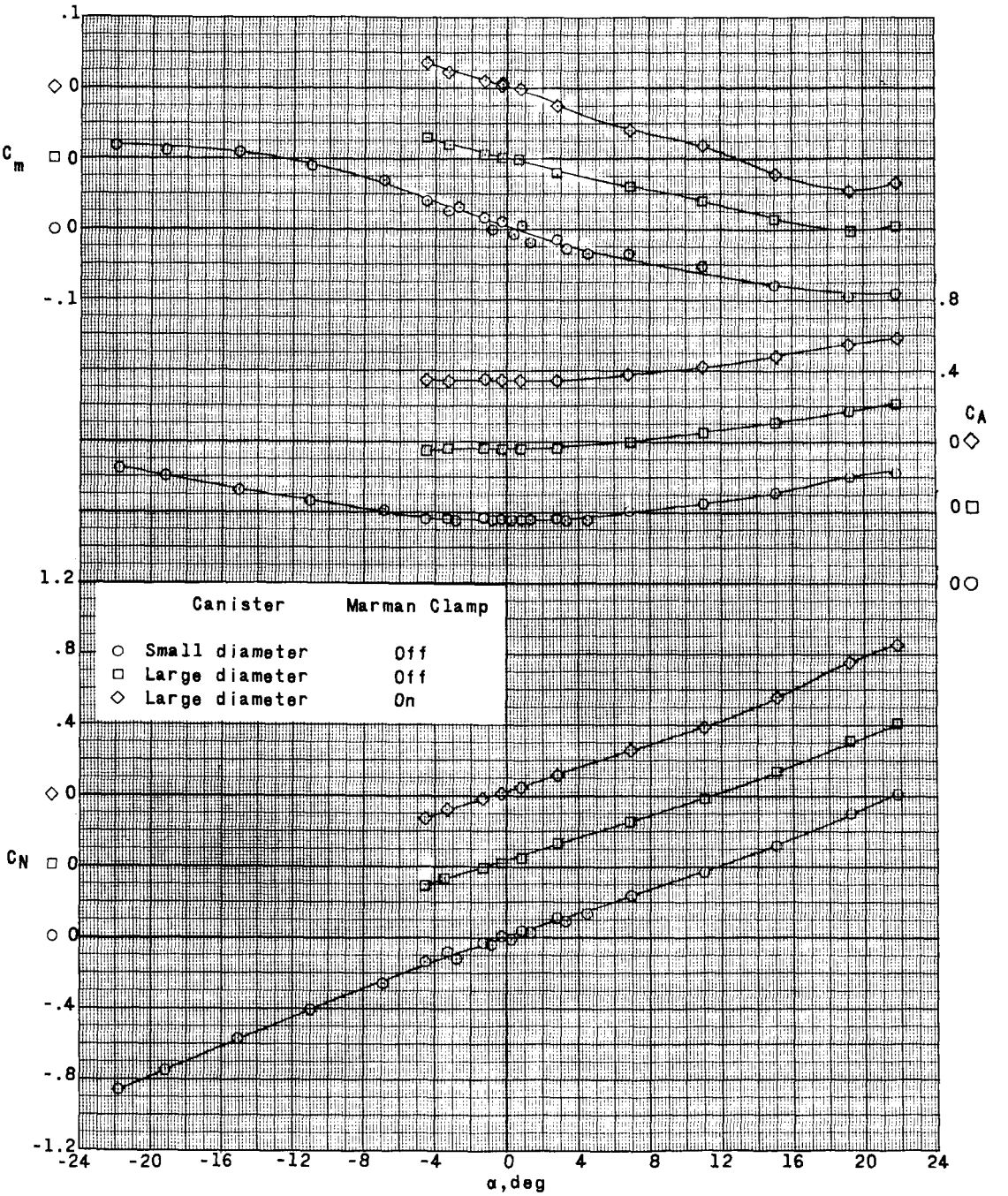


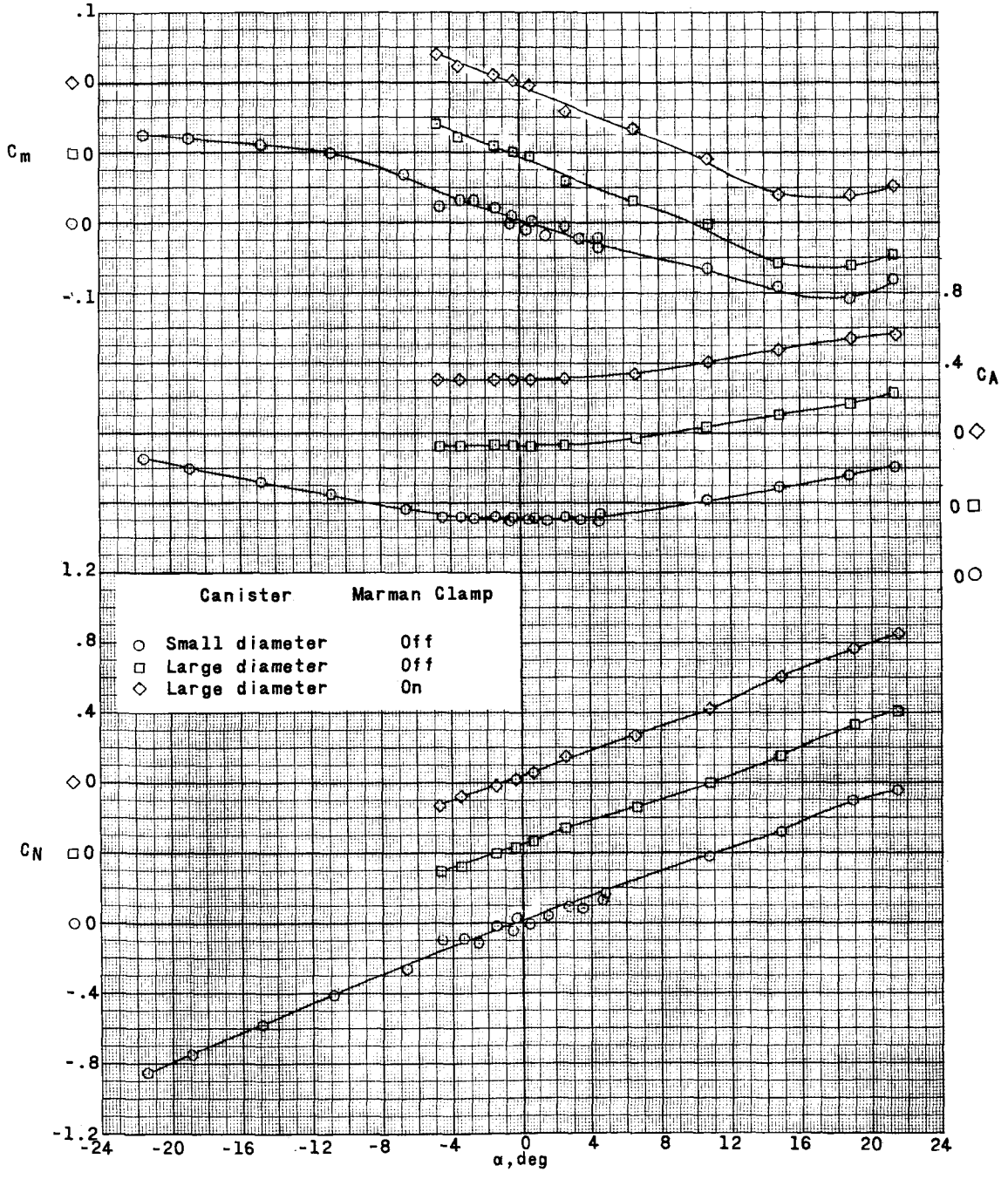
(b) M = 2.87.

Figure 8.- Continued.



(c) M = 3.94.

Figure 8.- Continued.



(d) M = 4.65.

Figure 8.- Concluded.

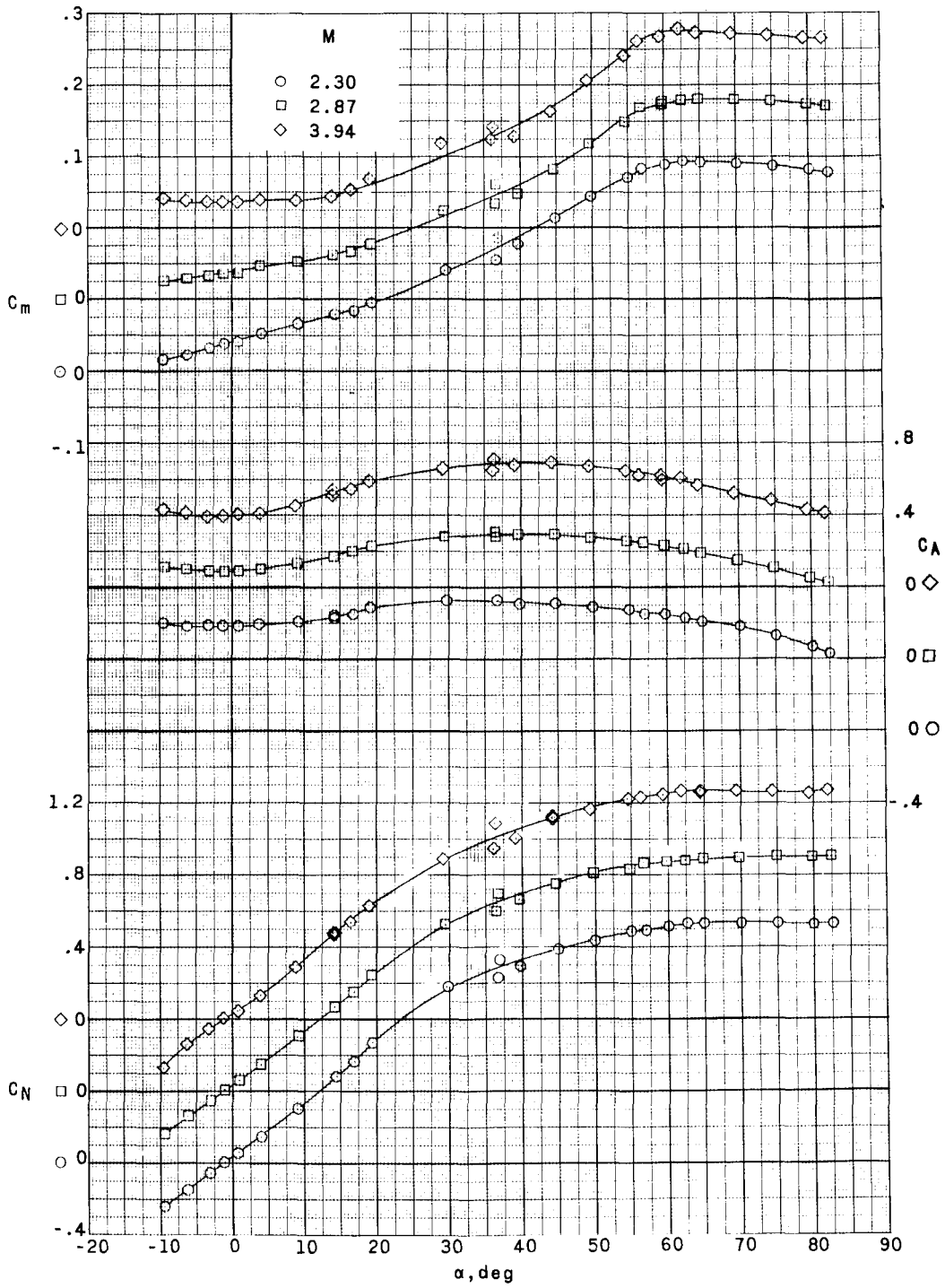


Figure 9.- Aerodynamic characteristics in pitch of the exit configuration.

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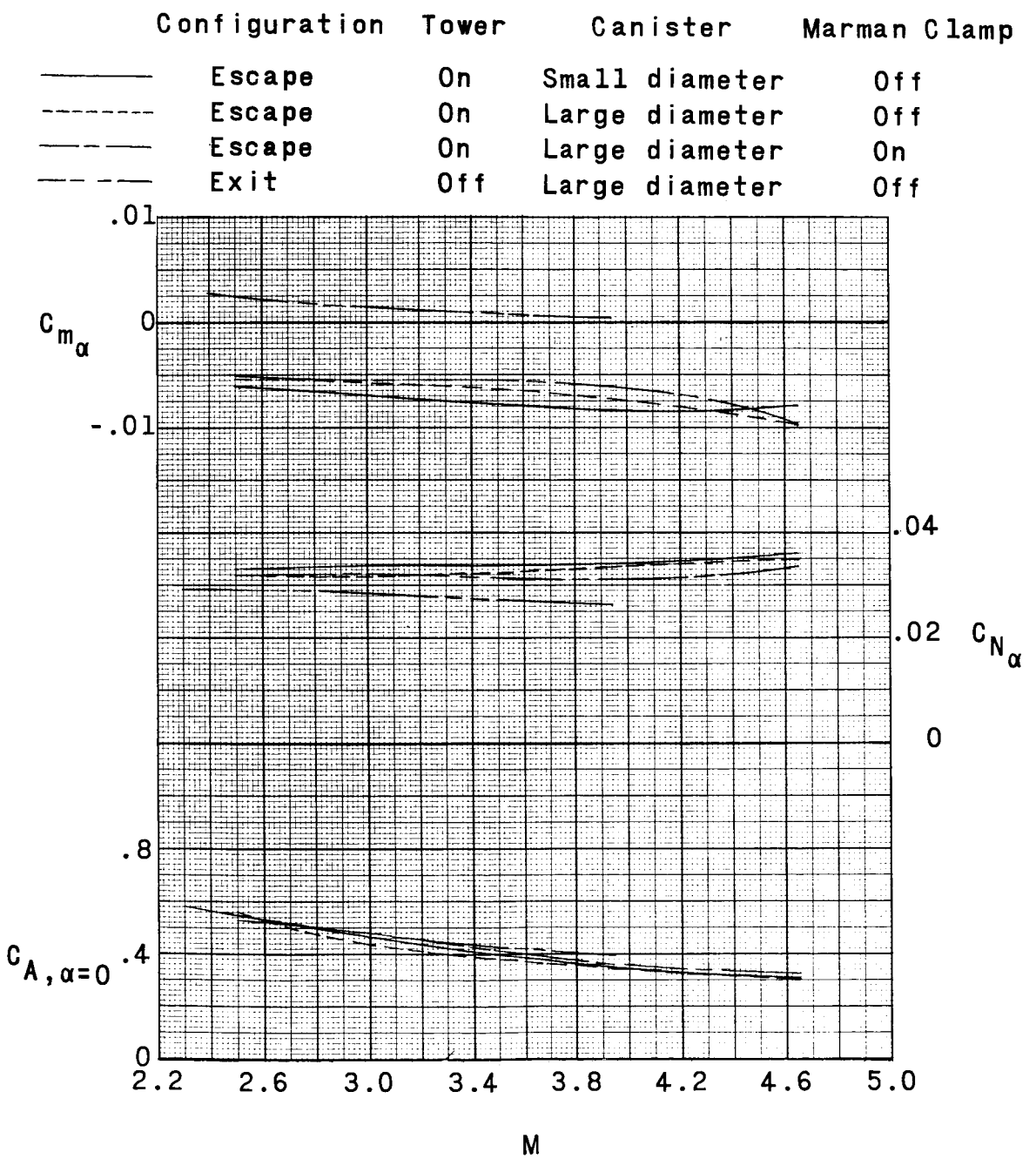

Figure 10.- Summary of the aerodynamic characteristics in pitch of the exit and escape configurations.

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